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Simulated Contact Tracing of COVID-19 Propagation at Kutztown University for Fall 2020

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ABSTRACT
From mid-May through August 2020 the author designed, built, revised, and analyzed resulting data from two simulation programs for virtual contact tracing of COVID-19 infection propagation at Kutztown University in the fall 2020 semester. The first was command-line driven and non-graphical, with results distributed to faculty and administrators on May 28. The second was a three-dimensional interactive graphical simulation, distributed to faculty, administrators, and the public as a narrated video via YouTube on July 16. The algorithm is an adaptation of *spreading activation* as used in theoretical psychology and artificial intelligence research since the 1970s. It propagates discrete, probable infections across a graph connecting face-to-face classes, tagging attending student and faculty members to the edges. The simulation is a state machine, advancing probable infections using a one-week time step and collecting resulting data at the end of each week. It uses class rosters to construct the graph, established parameters for COVID-19 propagation and risk, and student town party size and frequency measures based on interviews with local police and residents. Despite lower-than predicted employee infections in reported fall data, overall infections meet its predictions, indicating a higher infection rate and percentage of careless or unlucky students than initially assumed.

KEY WORDS
COVID-19, SARS-CoV-2, simulated contact tracing, spreading activation.

1. Introduction

In early March 2020 the human resources organization of Kutztown University informed employees of the plan to return to face-to-face teaching a week after the end of spring break. They communicated with faculty via the local union president. The author, who is a senior citizen aware of age-related risks, immediately set about getting medical excuse letters. The onus for establishing risks from COVID-19 infection for remote teaching was laid at the feet of the employees. By the end of spring break, thanks to a mandate from Governor Wolf, classes went fully on-line for the duration of the semester.

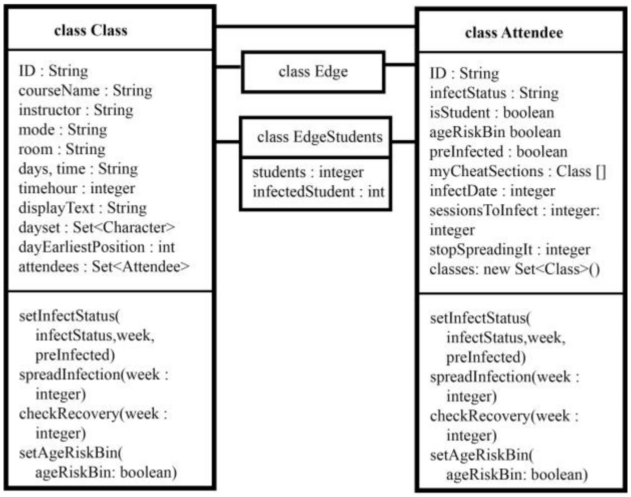
Immediately after final exam week the author pulled the May 16 rosters that identified fall classes, teaching professors, and enrolled students from the university database. The intent was to provide fall planners with a scientific analysis of probable COVID-19 propagation across the university population by writing and distributing simulation results based on detailed enrollment data. The initial white paper of May 28 was met with interest by the provost and several biology professors. These professors suggested improvements to the simulation model. The author incorporated professorial feedback and the results of further readings into a second, graphical simulation model distributed on July 16. While the viewer count for a narrated video recording of this model likely exceeds the readership of technical papers over the author's long career, the impact on university planning is unknown. A September 24 synchronous Zoom presentation of the final simulation results attracted only 17 members of the university community. The author aggregated daily infection counts provided by the university during the fall for comparison to the summer simulation results. This paper gives simulated and reported infection analyses through the end of the fall 2020 semester.

2. Roster-based Simulated Contact Tracing

2.1 Data Structures, Parameters, and Algorithms

Figure 1 shows the object-oriented class diagram for the main classes of the simulation. This diagram applies to both the original, command-line driven, non-graphical Python simulation of May and to the interactive, graphical simulation of June and July, coded in the Processing framework atop Java [1,2]. Both models use the same structure and algorithms, with all enhancements going into the graphical model after early June.

The class named *Class* houses data about a course offering typical of roster databases. The *Attendee* class houses data about a faculty member or student. There is one Class object for each course offering with some face-to-face attendance as of May 16, and one Attendee object for each attending faculty member or student as of May 16. An *Edge* object connects two Classes with its one-or-more Attendees in common.




```
loadData(classesCSV : String, studentsCSV : String, coursenumMap : String)
initSimulationState(R0 : float, seed : integer) : Attendee []
advanceState() {
  CONDITIONALLY initSimulationState(R0, null);
  simState(currentWeek, people);              // update simulation state
  advanceStatsPerWeek(currentWeek);           // update statistics database
}
simState(week : integer, peopleList : Attendee []) {
  for (Attendee p : peopleList) {
    p.checkRecovery(week);
    p.spreadInfection(week) ;
  }
}
```

Figure 1: Primary simulation classes

EdgeStudents is a related class that records number of student Attendees attending a pair of Class objects connected by an Edge, along with the number of infected students having those two Classes.

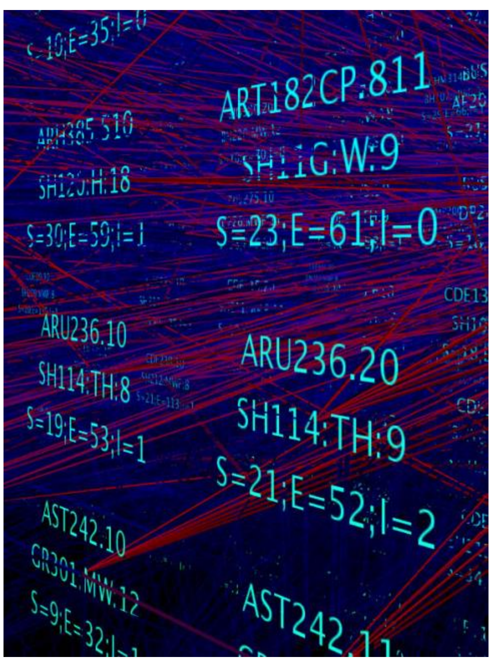


Figure 2: Sample of Class objects with Attendee edges

Figure 2 is a small corner of the three-dimensional, interactive, graphical object diagram of Class objects and their connecting Attendee faculty members and students. Each graphical Class object displays its course and section numbers, room number, day and time of its first class of the week, number of students "S", edges "E", and infected Attendees "I". Text color ranges from cyan for I=0 to yellow for I=S. An Edge connecting two Class objects is semi-transparent blue when none of its participating Attendees are infected, ranging to red when 100% of its Attendees are infected. Semi-transparency avoids obscuring the Classes with an opaque mass of Edges. An interactive user of the simulation can navigate through the 3D course graph as it steps through the 15 weeks of the fall 2020 semester and cycles to week 0 at semester's start.

Figure 3 on the next page shows the full array of 1238 face-to-face Classes with 5662 students and 339 faculty members as of May 16 [3], before additional course enrollments and late-August on-line reductions in face-to-face course modality for at-risk faculty members and students. The summary statistics at the bottom of Figure 3 are for week 3 during the second run of the 15-week semester. The simulation updates these statistics as it repeatedly runs through the weeks, allowing the user to navigate through the 3D Class graph, hide and reveal the edges and the summary statistics, and pause the simulation for closer inspection via navigation.

The 3D topology of Figure 3 groups Classes within a given department near each other, on the same 3D level where possible, in order to minimize cluttering Edge lines traversing levels for upper-level major students. However, due to the prevalence of general education courses and the existence of multidisciplinary majors, the graph is filled with Edges connecting remote Classes having students in common.

This statistical approach was inspired in part by a graphical simulation on the anticipated spread of COVID-19 at University of California at Los Angeles (UCLA) by four students [4]. That study is the only related infection propagation simulation to which the author had access in May. A prior study at Cornell University [5] that inspired the UCLA study was not publicly available until June 15, after the core simulation model of the current study was working with results published to Kutztown administrators and faculty. This report does not consider non-collegiate models. UCLA's study was more hypothetical than the current study, because as of May 13, UCLA was in the midst of moving as many fall courses as possible to on-line offerings: "Consequently, we are asking departments, divisions, and schools to plan to offer sufficient remote courses to provide all students with the options to fulfill department and degree requirements." [6] The UCLA simulation used a high-level statistical simulation model, in contrast to the more detailed, roster-based, simulated contact tracing of the current study. Nevertheless, the objective results are comparable. It is noteworthy that while UCLA was moving courses to on-line modalities in May, Kutztown University did not officially do so until two weeks before start of classes in August.

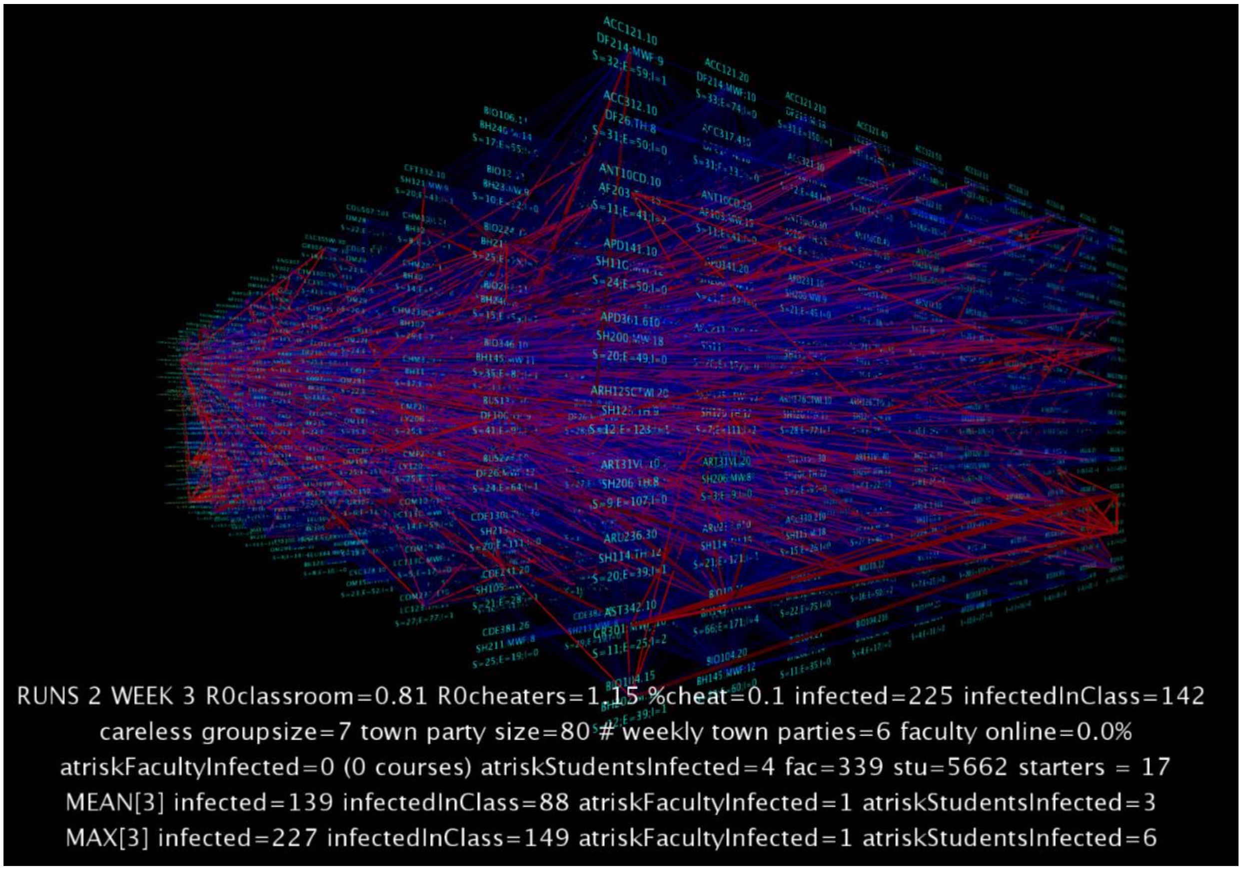


Figure 3: 1238 Classes with 5662 Students and 339 Faculty before On-line Accommodations

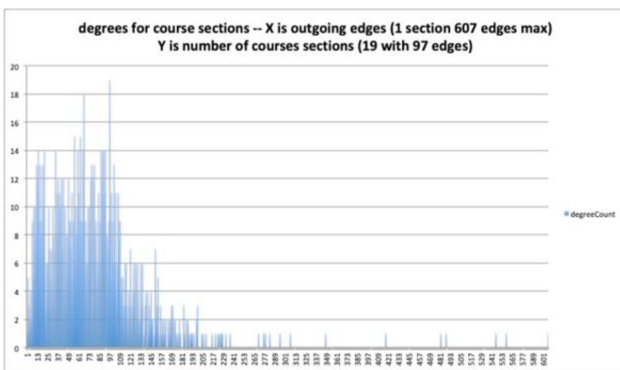


Figure 4: Connection Histogram for Figure 3

Figure 4 is a connection histogram for the graph of Figure 3, with the X axis showing the number of outgoing Edges for Class objects, and the Y axis showing the number of Class objects having X's number of Edges. The Class with the greatest number of connections to other Class objects via Attendees in common had 607 connections, and 19 Class objects with 97 Edges each comprise the statistical mode of this histogram.

The number of Class, Attendee, and Edge objects of Figures 3 and 4 reduced when Kutztown University granted faculty requests for 65% of face-to-face faculty to move on-line two weeks before the start of the fall semester. Only 211 Classes remained face-to-face, an 83% reduction thanks to faculty overloads, with 2454 students (57% reduction from 5662) and 118 faculty members. Furthermore, even for so-called hybrid classes where students were expected to attend a subset of the weekly face-to-face classes, attending via Zoom on other days, many faculty granted permission to attend remotely, reducing in-person class sizes and exposures. During the fall there were an estimated 2300 students living in dorms and another 1400 in town, totalling 3700 students, with many additional students attending remotely from home and not contributing to the simulation. The primary reason for the discrepancy between 2454 simulated students and 3700 estimated students is the number of students living in dorms or in town who nevertheless attended all courses on-line.

The differences in classroom infection numbers estimated in summer to reported infection numbers in Section 3 derive from the reduction in face-to-face Classes given in the previous paragraph. However, from May 16 until around August 10 the administration did not grant many requested course moves to on-line, so the number of actual face-to-face Classes was unknown until just before the fall semester. The present section focuses on planning and anticipation during the summer, when the face-to-face Class, Attendee, and Edge numbers of Figures 3 and 4 gave the only concrete estimates.

Before discussing algorithms for traversing the graph of Classes, it is necessary to define the primary simulation parameters applied by the model. Noteworthy is the fact that once coded, tested, and debugged, it was not necessary to change the model's code in order to match reported infection numbers during the fall. Adjustment of the following parameters was sufficient to adjust the model's predictions to match reported infection numbers.

R_0 (pronounced R-naught) is the key parameter for infection propagation. Intrinsically, it is the infection rate of the virus or bacterium. It is the basis of the exponential growth curves that have appeared all over the Internet and news in 2020. "R_0 tells you the average number of people who will contract a contagious disease from one person with that disease. It specifically applies to a population of people who were previously free of infection and haven't been vaccinated." [7] In this simulation, each week a person is infectious and in-class as constrained by conservative parameters **IncubationWeeks**=1 and **InfectiousWeeks**=1, that person randomly selects R_0 other people to infect. A value such as R_0=1.25 means that an infected person will infect one other person with a probability of 100%, and attempt to infect a second person with a 25% probability. R_0 values less than 1.0 yield decaying new infection numbers over time, while R_0 values greater than 1 spread infection exponentially. This simulation's infection process randomly selects an infected person's Class, and then randomly selects another person within that Class, for each of its R_0 attempted infections.

WEEK	NEW	TOTAL
1	8	8
2	9	17
3	12	29
4	15	44
5	18	62
6	23	85
7	29	114
8	36	150
9	45	195
10	56	251
11	70	321
12	87	408
13	109	517
14	136	653
15	171	824

Table 1: R_0=1.25 propagation from 6 initial infections

R_0 is the base for the exponential growth function R_0^{time}, where time in this simulation is a week 1 to 15, the length of a semester. R_0=1.25[1,15] with 6 incoming infected Attendees gives the Table 1 values for a semester. An incoming value of 6 infected Attendees is based on extrapolating spring 2020 student infections in the author's major department to the university population of students, with R_0=1.25 yielding a total of 824 on-campus infections, exactly matching the 412 reported X2=824 cases estimated for the fall as of the week 15, December 2 university report. The X2 multiplier is based on two assumptions. First, asymptomatic spreaders may constitute from 25% [8] to 70% [9] of infected Attendees, perhaps as high as 80% for student-age populations [10]. Second, widespread anecdotal evidence confirms that some percentage of symptomatic students began being tested at local pharmacies when tests became available in order to avoid campus quarantine. As informed by numerous studies, the X2 multiplier for university-reported infections is conservative. The university did not provide testing for asymptomatic Attendees in fall 2020. Mandatory repeated testing of asymptomatic individuals was a key recommendation of the Cornell study [5]. Spring 2021 has added rapid tests for all students only at the time of return to campus.

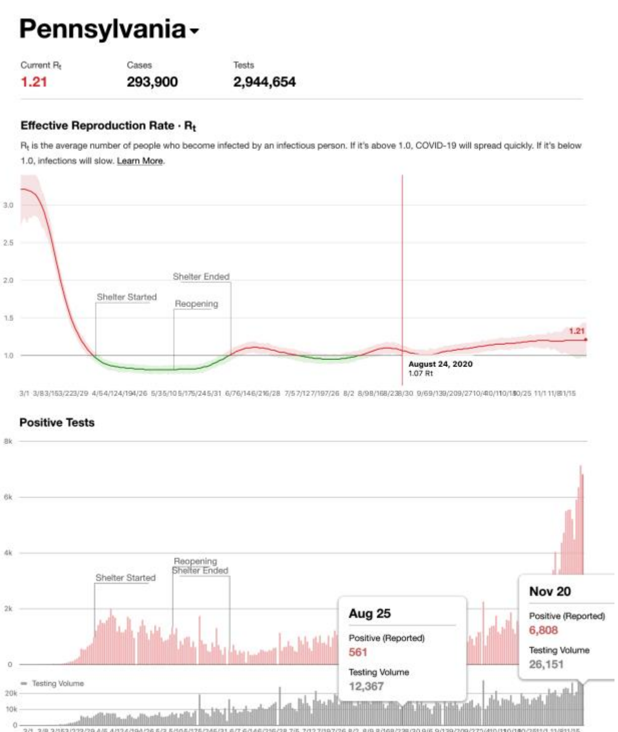


Figure 5: R_t, testing based estimated R_0 for 2020.

Figure 5 gives testing-based parameter values R_t for estimating R_0, along with positive results and testing volume in the bottom two histograms [11]. Contributors to https://rt.live/ have changed their presentation and analysis approaches in 2021, but the R_t value range and timing in Figure 5 was useful for estimating R_0 at Kutztown University and the surrounding community during summer and fall. Tagged dates at the bottom right of Figure 5 correspond to the start of semester and the return home before Thanksgiving break, followed by 100% on-line attendance through final exam week.

As previously cited, parameters **IncubationWeeks=**1 and **InfectiousWeeks=**1 are conservative estimates on how long it takes a freshly infected Attendee to become contagious, and how long an Attendee remains infectious. The values are conservative to avoid accusations of hyperbole. The time quantum for the simulation is one week.

The simulation's **Asymptomatic=.25** (25%) estimate does not affect results significantly, because the assumption is that both symptomatic and asymptomatic Attendees would propagate the disease. The **InstructorsAtRisk=.25** parameter – 25% of faculty members could be at risk for severe effects if infected – comes from a Kaiser Family Foundation study [12]. KFF was an extremely useful source of information in addition to the Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO). KFF gave a comparable estimate of 24% for at-risk teachers [13]. Because of the high reported rate of asymptomatic young people and the desire to avoid overestimation, the simulation uses a conservative estimate of **StudentsAtRisk=.025**, one tenth the parameter for instructors.

Parameter **facultyRequestingNoF2F** ranged from 0% at the start of summer when no accommodations were promised, through 33% based on documented requests to Human Resources in the spring and 52% from a summer faculty union survey, to the actual 65% discussed in the right column under Figure 3. Simulation results in Section 3 are based on this **facultyRequestingNoF2F=.65** value.

Estimating cheating (i.e., ignoring safety guidelines) among Attendees, primarily students, requires bifurcating **R_0** into two values. **R0classroom=0.81** corresponds to the R_t dip in late July in Figure 5. Classroom remediation included 6 feet of distancing, masks, and hybrid classes, but remediation of ventilation was minimal. **R0cheaters=1.45** for Attendees attending parties or other careless gatherings, or being collateral damage of such students, was the summer estimate for fall numbers based on a conservative interpretation of Figure 5 values. Parameter **percentCheaters=0.15** is a percentage of all Attendees. Furthermore, weekly **cheatersPerTownParty =80**, **numTownParties=6** per week, and **cheatersPerMeeting=7** for careless non-party gatherings are based on interviews with local police, residents, and alumni. A local policeman told the author, "Two houses on Thursday four on Friday and one on Saturday. Crowds range from approximately 35-125 these are the averages I have experienced. There were 8 houses 7 houses that regularly held large gatherings and there are often a half a dozen smaller one occasional parties and of course holidays and special occasions." [14] Despite feedback from a biology professor in June that most spread occurred via large super-spreader events, the author maintained **cheatersPerMeeting=7** for non-party careless gatherings in locations such as dorm lounges, a model aspect that coincides with later warnings about family gatherings at Thanksgiving and Christmas [15]. Small numbers of people engaging in other gatherings can contribute significantly to interconnections in the contact graph.

The model represents house parties and smaller careless gatherings as Class objects with Community-prefixed names. A notable bug appeared when the author started by modeling a single Community Class object where all cheating Attendees with **R0cheaters** gathered. It became a super-spreader of infection in the graph. It was at this point that the author researched the size and number of house parties [14] and allocated multiple Community Class objects according to the **cheatersPerTownParty**, **numTownParties**, and **cheatersPerMeeting** parameters.

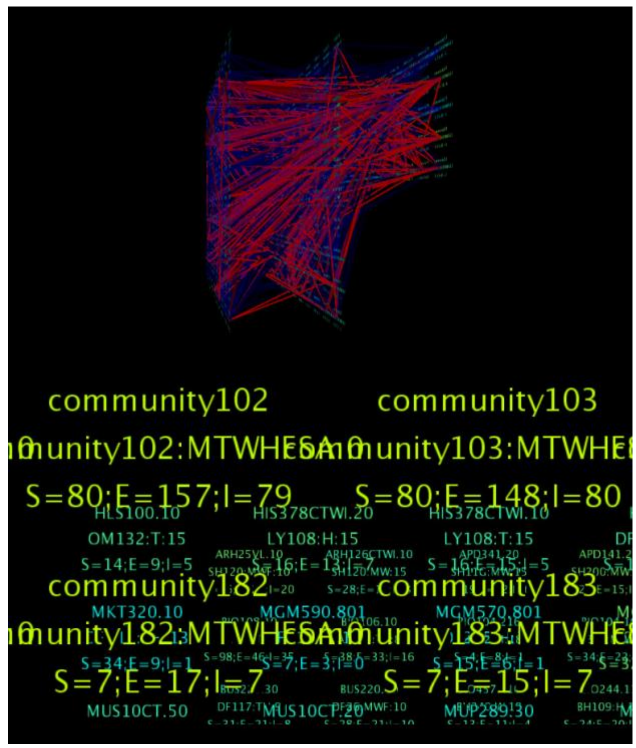


Figure 6: Community Spread at House Parties

Figure 6 shows two snapshots of a single simulation run. The graph at the top shows week 3 infection propagation in red. Early in the semester, large house parties at the upper right serve to propagate infection rapidly across many students who then carry it back into the campus community. The Class objects at the bottom show two party and two small gathering Community objects at week 11. By this time essentially all of these Community Attendees have been infected. As Section 3 discusses, this appears to be an accurate simulated representation of the fall 2020 conditions. Most infection propagation occurred outside the classrooms, then bringing infections into classrooms and other campus settings.

Listing 1 below summarizes the main algorithms that work with these graphs and simulation parameters. Function **loadData**() reads the comma-separated value data from the roster databases for classes, students, and course number associations into internal data structures. Function **initSimulationState**() re-initializes simulation at the start of each 15-week cycle. Simulation is stochastic, so the exact courses retained when **facultyRequestingNoF2F** is greater than 0%, and the exact Attendees infected or cheating, vary from semester cycle to cycle. The simulator maintains current, average, and maximum measures for all cycles through the semester. An analysis from Santa Fe Institute recommends keeping track of the maximums. “R-naught is just an average: the transmission rate varies widely, and outbreaks can be surprisingly large even when the epidemic is subcritical.” [16]

```
loadData(classesCSV : String, studentsCSV : String,
coursenumMap : String)

initSimulationState(R0 : float, seed : integer) :
Attendee []

advanceState() {
  CONDITIONALLY (at start of semester)
             initSimulationState(R0, null);
  simState(currentWeek, people);
            // update simulation state
  advanceStatsPerWeek(currentWeek);
            // update statistics database
}

simState(week : integer, peopleList : Attendee []) {
  for (Attendee p : peopleList) {
    p.checkRecovery(week);
    p.spreadInfection(week) ;
  }
}
```

Listing 1: Main simulator pseudo-code

Function advanceState() is the simulation state machine driver. It invokes initSimulationState() at the start of each semester cycle, then alternates between updating simulator state in simState() and updating a statistics database of means, maximums, and other measures derived from simulator state in advanceStatsPerWeek(). Function simState() checks each Attendee for recovery, and then spreads infection from infected Attendees.

Attendee method spreadInfection(week : int) implements *spreading activation* [17] as employed in this simulation. Incubation takes IncubationWeeks before becoming infectious and lasts for **InfectiousWeeks**. Both parameters are currently set at 1 because of the per-week time resolution of the model and to yield conservative estimates. **For each infected Attendee, spreadInfection() applies parameter R0classroom to randomly select one or more Class objects and an uninfected and unrecovered Attendee within each Class for new infection. A fractional value such as R0classroom=.81 results in infecting an Attendee with an 81% probability. For each infected cheater Attendee, so tagged by initSimulationState() based on parameter percentCheaters, spreadInfection() also applies parameter R0cheaters to randomly select one or more Community Class objects and an uninfected and unrecovered Attendee within each Community Class for new infection. A value such as R0cheaters=1.45 results in infecting one Attendee with a 100% probability and a second with a 45% probability.**

2.2 University Response

Section 3 gives simulation results compared to infection measures reported by the university. That comparison required waiting for concrete fall data through December 2020. This section summarizes university response in summer 2020.

The white paper based on the command-line parameterized Python simulation model went to faculty, administrators, and the members of the university’s Emergency Management Team (EMT) on May 28, 2020. The provost emailed the author that same evening to express that she had read the paper quickly, was interested in the simulated contact tracing mechanism, and would read it again. No other response from the administration ever occurred.

As noted earlier, several biology professors provided useful feedback. One spotted a bug in calculating the number of disrupted classes when an at-risk professor went out sick – the average should have been 4 classes per professor, not 1 – and another helped to refine R_0 estimations. Several pointed at additional useful sources of information. The author sent these biology professors a revised copy of the white paper incorporating their feedback on June 2.

The author distributed the three-dimensional interactive graphical simulation to faculty, administration, and the public as a narrated video via YouTube on July 16 [3]. The video emphasizes the role that house parties and careless informal gatherings were likely to play in spreading infection. The author received a short response from the provost pointing to the code of conduct concerning distancing, masks, and other precautions that the administration would distribute to students. No other response to the video from the administration ever occurred.

The narrated video garnered 804 views during its first 2.5 weeks on YouTube and has reached 985 views as of March

2021. There was substantial response from faculty members in the first two weeks, most of it positive. There were a few contrary responses and one faculty member who requested never to receive such email again.

The author received a text message from a member of the Emergency Management Team (EMT) a week or so after distributing the video, implying that the author would be invited to review the initial EMT plan within a few weeks. About two weeks later he received a short apology, implying that the invitation would not occur.

There were no scientists on the EMT. Not one professor from biology or any other STEM department contributed to planning. There were no faculty members at all until a staff member on the EMT insisted. The EMT's membership and activities were mostly political. The top local union leaders acted as mouthpieces for the administration. The PA State System chancellor and the university trustees gave unwavering support for the administration and the plan. Mandates from the governor were implemented, although an audit of classroom distancing resulting in an August downward revision to the number of students planned per hybrid classroom. Air treatment received little remediation. There was no testing of students on return to campus, despite the fact that the initial number of infected Attendees has a significant effect on the starting point for exponential spread. There was no sampling of asymptomatic students for infection. The final two weeks of class were 100% on-line. Spring 2021 has seen rapid testing of all returning students, with the first two weeks of classes on-line to allow for holiday infections to stabilize, but still no sampling of asymptomatic students for infection during the semester. Substantial anecdotal evidence indicates that many students suspecting infection went to local pharmacies for testing in the fall, instead of the university, in order to avoid quarantine. There is no available data regarding such testing.

Each day the university distributes a table summarizing reported infections to faculty, staff, and students. Table 2 is the table from December 22, 2020. There were no measures for hospitalizations, infection of at-risk Attendees, or number of faculty members. As previously noted, there was no testing of asymptomatic Attendees or Attendees testing at local pharmacies.

Positive cases	Today 12/22	This week 12/21-25	Total cases since 8/24	Active cases	Recovered cases
Students living on campus	0	0	158	1	407
Students living off campus	1	1	250		
Employees	5	5	19	4	15
Total	6	6	427	5	422

Table 2: University daily report for December 22

The author suspects that a suggestion in the May 28 white paper to give a lavalier microphone to every faculty member teaching face-to-face or hybrid classes may have been the source of that remediation, but this is unknown. As far as the author can tell, nothing in the reports had any effect on planning. Certainly, testing all returning students and sampling asymptomatic Attendees regularly in the fall could have reduced the number of infections. Those science-based recommendations were ignored.

3. Aligning Simulation with Reported Data

Figure 7 on the next page gives per-week infection counts for Kutztown University in red as reported on Wednesdays during the fall semester. The blue curve is for Bloomsburg University of PA. The green curve is simply the red Kutztown University curve multiplied by the X2 multiplier to estimate the infection of asymptomatic Attendees discussed in Section 2.1. Finally, the purple curve is the simulated infection curve discussed with Figure 9 below.

Figure 8 gives percentages of students for the Kutztown University and simulated curves of Figure 7. By December 2, 11.14% of the 3700 students living on campus or in town (2300 campus + 1400 town), 412 students, were reported as having been infected. The X2 doubling for asymptomatic Attendees gives 22.27% (rounding to two decimal places) of the student body infected.

While Figures 7 and 8 are based primarily on reported data, Figure 9 and the SIM8Feb2021 curves of Figures 7 and 8 are based on a simulator run of February 8, 2021, that attempted to match simulated results with reported results X2. The achieved target was to match week 15 simulated numbers to reported numbers X2. This required some rather concerning adjustments to simulation parameters.

R0cheaters=3.5 is up from the 1.45 value anticipated during the summer. **percentCheaters=0.2** (20%) is up from the 0.15 value anticipated during the summer. **R0classroom=0.6** is down from the 0.81 value anticipated during the summer. **numTownParties=7** per week is up from 6 and in agreement with the police officer interview, and **cheatersPerMeeting=8** is up from 7. Parameter **cheatersPerTownParty=80** is unchanged, although some parties exceed that value.

The increases were necessary to reach a prediction of 846 mean infected matched to the X2 reported count of 824, in conjunction with decreasing **R0classroom** from 0.81 to 0.6 to account for lower-than expected at-risk faculty infections. Increasing **R0cheaters**, **percentCheaters**, **numTownParties**, or **cheatersPerMeeting** increases the final simulated infection count, while decreasing **R0classroom** in order to match lower-than-expected infected faculty count also decreases the final infection count. Temporal curve mismatches occur because R_0 varies during the semester, based in part on super spreaders and moving indoors.

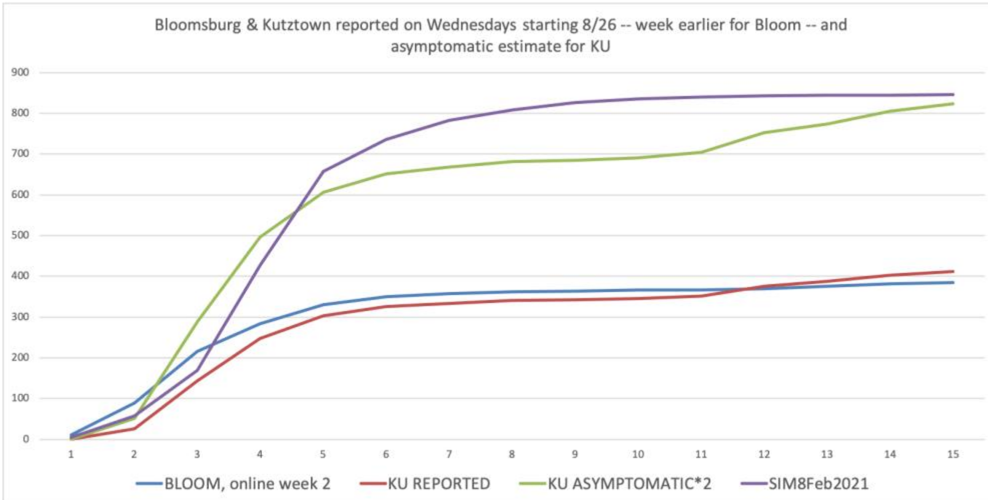


Figure 7: Reported and Projected Infections for Fall 2020

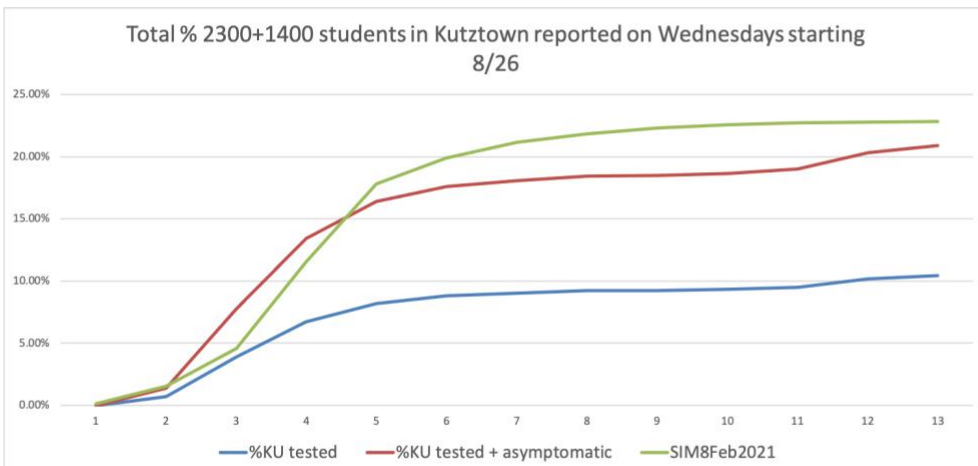


Figure 8: Reported and Projected Percentages of Students for Fall 2020

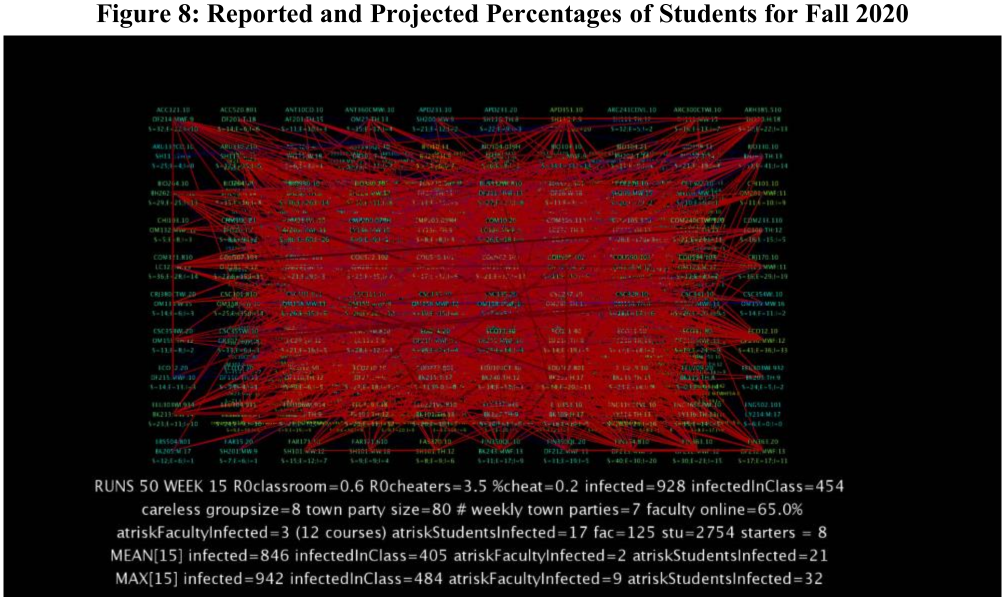


Figure 9: Screen shot of February 8, 2021 Simulation of Fall 2020

The December 2 campus report states there were 8 total employees infected during the semester. If we assume that all 8 were faculty members (some were most likely administration and / or staff) with **InstructorsAtRisk=.25** as previously discussed, the 2 at-risk faculty reported in Figure 9 agrees with the campus report count of 8. Some faculty-age Attendees may have been asymptomatic or under-reporting, but the numbers are down in the single or low double digits. Reducing **R0classroom** required increasing **R0cheaters**, **percentCheaters**, **numTownParties**, and **cheatersPerMeeting** to get to the infection count range of Figure 7.

The adjustments to parameters means that, according to the simulation, 20% of students were going to parties or otherwise being careless, a figure that agrees with the 22.27% of students infected in the X2 red curve of Figure 8. One of the author's undergraduate research collaborators who works for the university IT organization successfully requested not working in the dorms because "the dorms are crazy" with respect to non-conformance to guidelines. To reach the total of approximately 824 Attendees, each of the reckless infected 3.5 other people on average. R_t=3.5 is the worst estimated R_0 value for the state during the early pandemic as plotted in Figure 5. The simulated curves of Figures 7 and 8 pass the X2 reported curves at 4.5 weeks, but the simulated and reported curves converge by week 15. Moving activities indoors in early November at week 11 may account for the acceleration in reported counts.

On March 17, 2021 – the middle of week 7 of face-to-face classes and week 9 overall of the spring semester – there were 84 total reported infections including 19 employees, down from 334 total reported cases in week 7 and 342 in week 9 of the fall, with only 3 total employees summed in week 7 and 4 in week 9 in the fall. While vaccinations are rightfully receiving credit for some of the decrease in infection community counts, Berks County has reported several spikes in March [18,19].

It is likely that the improved student infection counts so far in spring 2021 are the result of temporary immunity of party-going and otherwise careless students who were infected in the fall. The author has been in contact with students who were infected in spring 2020 and who were infected a second time in the fall. The author is in contact with students who are infected now. The lower student counts in spring 2021 are not a cause for undo optimism leading to plans for face-to-face commencement in May and full face-to-face reopening of classes with no classroom remediation in the fall [20]. With new viral variants on the increase, caution remains important.

The steep gradient of simulation curves of Figures 7 and 8 flatten earlier than the X2 reported counts in order to converge by week 15. Unlike reality in which R_0 changes from week to week depending on factors such as closing windows and moving recreational activities indoors, the simulation R_0 values are fixed for a given run. It is possible to have a stepped simulated R_0 sequence, but there is really no way to predict its values. In any case, it appears from the curves that partiers and other careless Attendees saturated their ranks. Partiers appear to have achieved internal herd immunity, at the cost of substantially increased risk to the surrounding community. There is no reported data about long term effects on these people.

Nightly news carried stories of reckless Super Bowl parties in February and spring break in March. Infection numbers may be much higher than the daily reports [21]. We are mostly living indoors with inadequate ventilation and with large portions of the U.S. population ignoring guidelines. Concerned people need to stay educated, informed, and vigilant until this is over.

4. Conclusions

It appears from reported numbers that classrooms were not the primary locus of infections, both because of remediation and also because of permission for students in many hybrid classes to attend remotely. Nevertheless, reducing the **R0classroom=0.6** value further downward results in too small a final infection number. Based on the simulation, infections were still likely passed in inadequately ventilated classrooms and hallways connecting them. On the other hand, partying and other careless behavior certainly played a bigger role than the author's conservative modeling estimation during summer 2020. The model presented here is much more accurate in taking student behavior into account than one from the University of Illinois. 'What the scientists had not taken into account was that some students would continue partying after they received a positive test result. "It was willful noncompliance by a small group of people," Goldenfeld said.' [22].

It would have been nice if university science and scientists had played a role in planning, at least in insisting on incoming and asymptomatic testing at Kutztown.

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